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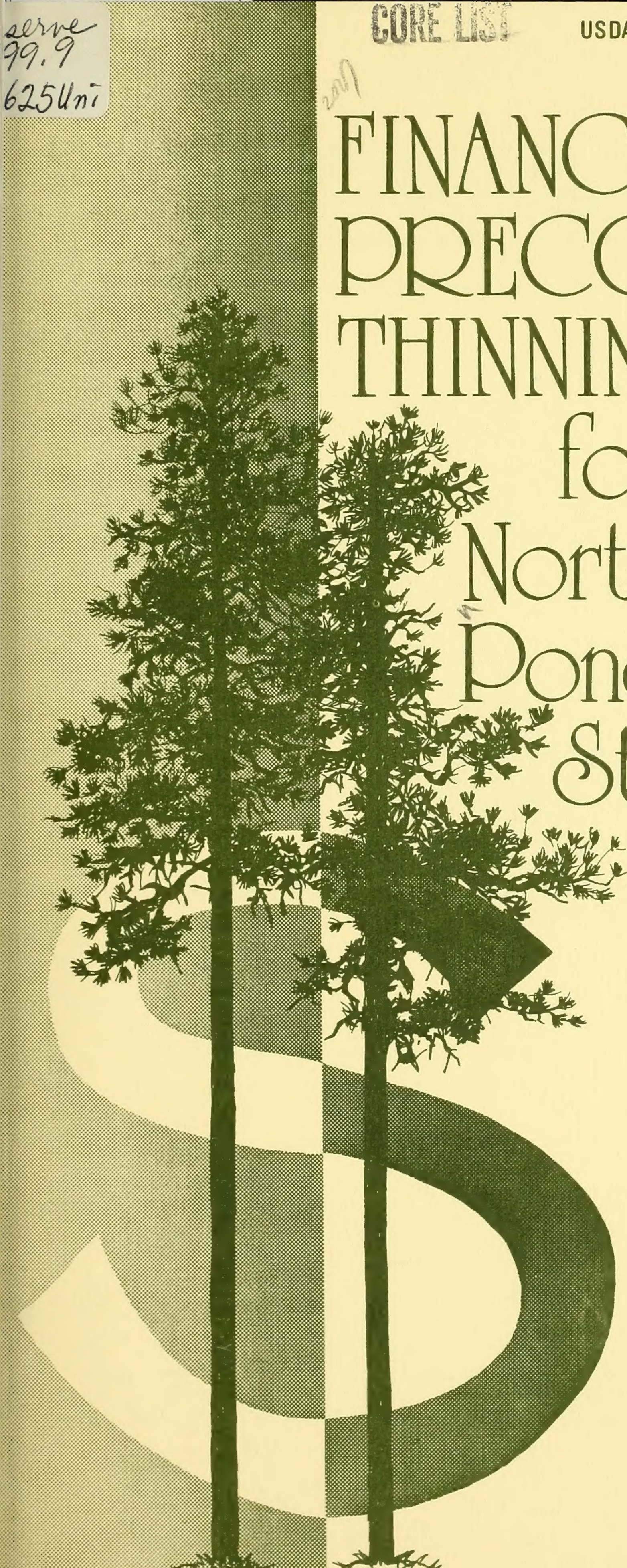
FINANCIAL PRECOMMERCIAL THINNING GUIDES for Northwest Ponderosa Pine Stands



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Metric Equivalents

1 acre = 0.405 hectare

1 foot = 0.3048 meter

1 inch = 2.54 centimeters

1 square foot per acre = 0.229 568 square meter per hectare

FINANCIAL PRECOMMERCIAL THINNING GUIDES FOR NORTHWEST PONDEROSA PINE STANDS

Reference Abstract

Sassaman, Robert W., James W. Barrett, and Asa D. Twombly.
1977. Financial precommercial thinning guides for Northwest ponderosa pine stands. USDA For. Serv. Res. Pap. PNW-226, 27 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

This paper describes a flexible management tool designed to be applicable to thinning alternatives for an infinite number of combinations of crop tree size and vigor, site quality, thinning costs, stumpage prices, and three discount rates.

KEYWORDS: Precommercial thinning, thinning (precommercial), improvement cutting, forestry business economics, economics (forestry business), site class, diameter increment, increment (diameter), stumpage prices, cost and return accounting (forestry), timber management planning, ponderosa pine, *Pinus ponderosa*, Pacific Northwest.

RESEARCH SUMMARY

Research Paper PNW-226

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Financial precommercial thinning guides for Pacific Northwest ponderosa pine (*Pinus ponderosa* Laws.) stands are reported for an infinite number of combinations of crop tree size and vigor, site quality, thinning costs, stumpage prices, and three discount rates. These guides are the result of a cooperative effort of the Pacific Northwest Forest and Range Experiment Station and Region 6 of the National Forest System (NFS). The guides represent a flexible forest management tool that is based on financial returns from increased timber production expressed as benefit/cost ratios; they are of most use to NFS managers.

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INTRODUCTION

Forest managers in the ponderosa pine (*Pinus ponderosa* Laws.) areas of the Pacific Northwest are often faced with the responsibility of establishing precommercial thinning priorities for timber stands of widely varying location, size, and growth characteristics. The thinning priority of an individual stand may be influenced by consideration of a variety of resource uses and concerns. Financial implications (costs and benefits) associated with the estimated harvestable wood production of thinned stands often have a major impact on the selection of thinning priorities.

This paper describes the development and use of financial precommercial thinning guides for stands of ponderosa pine in the Pacific Northwest. These guides are the result of a cooperative effort of the Pacific Northwest Forest and Range Experiment Station and Region 6 of the U.S. Forest Service. They are a flexible management tool designed to be applicable to thinning alternatives for an infinite number of combinations of crop tree size and vigor, site quality, thinning costs, stumpage prices, and three discount rates. The paper was written primarily to help National Forest System (NFS) managers identify their most financially attractive precommercial thinning opportunities.

The guides are based on a stand analysis (rather than a forest analysis) approach and on numerous NFS policies determined on other than a financial basis.1/ Therefore, the value of these guides to industrial forest managers and other public forest managers will be limited to the extent that their agency's policies agree with the assumptions built into these guides.

Financial precommercial thinning guides are important to forest managers in two ways. First, since opportunities to thin usually exceed what the budget can finance, forest managers can accomplish more with their budget by using the guides to select the most financially attractive precommercial thinning opportunities.

1/ Use of a stand analysis excludes consideration of any effects that precommercial thinning may have on the flow of timber harvests on a forest. As such, a stand analysis does not include consideration of the allowable cut effect (Schweitzer et al. 1972) or any other forestwide timber harvest flow constraints. The most direct application of a stand analysis is to set financial priorities among stands for treatment. Costs and benefits not measured in dollars must also be considered when final priorities are set. At higher levels of decisionmaking, additional evaluations of programs of treatments may be needed. A thinning program may have important environmental, esthetic, and wildlife impacts not considered in a stand analysis. At this level, the impact of the program on the allowable cut level and the cash flow from the unit will also likely interest decisionmakers.

Second, these financial precommercial thinning guides are important to forest managers because they provide a consistent regionwide approach to identifying the most financially attractive precommercial thinning alternatives. This consistency will benefit the forest manager when he attempts to set thinning priorities based on the financial ranking and the nontimber and amenity values of the alternatives.

DESCRIPTION OF THE GUIDES

The thinning guides are represented by benefit/cost ratios (B/C) determined through a marginal financial analysis of the thinning alternatives. B/C is one of several ways economists have developed to judge competing financial investments. The theoretical reason for its use in this analysis is the presence of a budget constraint. If we could assume that all required funds would be available, then a budget constraint would not exist and present net worth would be a more appropriate criterion (Webster 1965). In its simplest form, a B/C for a thinning investment is obtained by dividing the benefits of a thinning project by the thinning costs:

$$\frac{\text{benefits of thinning}}{\text{costs of thinning}} = \text{benefit/cost ratio.}$$

Usually, the analysis is more complex because the timing of the benefits and costs is important. Precommercial thinning costs are incurred immediately, but the benefits are not realized until the time of the commercial thinnings and the final harvest. Because society places a time preference on money (one would normally prefer "x" dollars today than sometime in the future), the future benefits of thinning must be reduced to reflect their present value before dividing them by the cost of thinning, already expressed in present value, to obtain a B/C. Therefore, the B/C is more aptly stated as:

$$\frac{\text{present value of benefits of thinning}}{\text{present value of costs of thinning}} = \text{benefit/cost ratio.}$$

The reduction of future benefits to present value is called discounting. The discount rate is the interest rate used to reduce future benefits and costs to their present value. Agency policy will dictate the proper discount rate.

B/C is a convenient vehicle for comparing investment alternatives because it is a relatively simple numerical index. A B/C greater than 1.0 indicates that measurable benefits exceed measurable costs. The more a B/C exceeds 1.0, the more financially attractive is the investment (and the better the thinning opportunity). When the B/C equals 1.0, benefits and cost are equal. When a B/C is less than 1.0, measurable costs exceed measurable benefits. And, if a B/C is equal to zero, there are no net measurable benefits to consider, only costs.

A note of caution is in order. One might conclude that a thinning alternative with a B/C of less than 1.0 should automatically be eliminated from further consideration and that thinning priorities should be based on higher B/C's ahead of lower ones. Such a conclusion would be premature, however, because although a financial evaluation of measurable costs and benefits is important in selecting precommercial thinning opportunities, amenity values that are not readily translated into dollars often need to be considered. These values include esthetics, dispersed recreation opportunities, wildlife habitat, and fire danger reduction. These values may be costs or benefits. Therefore, the most important point to remember in the use of these guides as a ranking tool is that they provide only a financial ranking and that final priorities must consider other costs and benefits omitted from the B/C.

Use of B/C is appropriate for our analysis of precommercial thinning alternatives, since our main concern is to *rank* thinning alternatives and thereby identify the most financially attractive ones for funding rather than to determine a specific rate of return for each thinning alternative.

In a B/C analysis of precommercial thinning alternatives, the benefits are expressed as a stumpage price in dollars per thousand board feet ($/MBF) times the additional volume of timber that will be available for harvest in commercial thinnings and the final harvest as a result of the precommercial thinnings. Present value of the benefits is obtained by discounting the benefits to year zero. Costs, expressed in dollars per acre, occur in year zero so they are already expressed in present value and need not be discounted.

Table 1 illustrates a typical B/C calculation for a precommercial thinning alternative; in this case, a stand with high vigor 2-inch crop trees on a high site. Stumpage price is $40 ($30 for commercial thinnings), precommercial thinning costs are $25 per acre, and the discount rate is 5 percent. Column 7 shows the discounted revenue (the present value) of each commercial thinning and the final harvest for situations both with and without a precommercial thinning. The present value of the benefits of the precommercial thinning is the difference of the present values listed in column 7 both with and without precommercial thinning ($28.39-$1.61). The B/C ($1.07) is the difference ($26.78) divided by the cost ($25.00).

A similar calculation could be made for an infinite number of combinations of crop tree diameters, vigor, sites, thinning costs, and stumpage prices. The results of such calculations could be summarized in voluminous tables such as the examples in appendix C for selected costs and prices at a 5-percent discount rate.

Table 1--*An example of the method used to calculate benefit/cost ratios (B/C) for the economic precommercial thinning guides with sample data representing a stand with high vigor 2-inch crop trees on a high site; a 5-percent discount rate is assumed*

1	2	3	4	5	6		7		8	9
Age	Time since precommercial thinning	Volume harvested		Type of harvest[1/]	Harvest revenue[2/]		Present value of revenue (discounted at 5 percent to year 0)		Precommercial thinning cost	Present value of precommercial thinning cost[3/]
		With precommercial thinning	Without precommercial thinning		With precommercial thinning	Without precommercial thinning	With precommercial thinning	Without precommercial thinning		
- - - Years - - -		Board feet per acre			- - - - - - - - - - - - Dollars per acre - - - - - - - - - - - -					
13	0	--	--	--	--	--	--	--	25.00	25.00
37	24	1,324	--	CT	39.72	--	12.32	--	--	--
60	47	2,891	--	CT	86.73	--	8.76	--	--	--
80	67	3,440	--	CT	103.20	--	3.93	--	--	--
100	87	--	2,210	CT	--	66.30	--	0.95	--	--
120	107	--	2,688	CT	--	80.64	--	.44	--	--
127	114	21,980	--	FH	879.20	--	3.38	--	--	--
140	127	--	2,792	CT	--	83.76	--	.17	--	--
214	201	--	21,383	FH	--	855.32	--	.05	--	--
Total							28.39	1.61		

Present value of the benefits of thinning = \$28.39 - \$1.61 = \$26.78.

$$B/C = \frac{\$26.78}{\$25.00} = \$1.07.$$

1/ CT is commercial thinning; FH is final harvest.

2/ Based on stumpage prices of \$40 per thousand board feet for final harvests and \$30 for commercial thinnings.

3/ Present value of precommercial thinning cost is the same as the precommercial thinning cost because it is incurred at year 0 and, therefore, is already expressed as present value.

The problem with this approach is that the user must interpolate B/C values when the precommercial thinning cost-stumpage price combination associated with a thinning alternative is not listed in the B/C tables. If both the cost and the price are not represented in the tables, a double interpolation is required to obtain the relevant B/C. Since a double interpolation is a time-consuming and error-prone procedure, we devised a simpler approach that replaces each B/C table with a B/C factor (F). Consequently, the 16 tables of appendix C could be replaced by 16 B/C factors. These factors, listed in table 2, permit users to calculate B/C's for their thinning alternatives with a simple formula: B/C = F x final harvest price/cost, or B/C = F x P/C. The "Use of the Guides" section shows how to calculate the B/C's by this formula with the worksheet described in figure 1 to construct the thinning guides. A section outlining the derivation of the B/C factors follows, but first observe that the formula containing the B/C factor will produce the same answer (1.07) with the sample data as the typical longer B/C calculation used in table 1. The F value was obtained from table 2 for a high site, high vigor, 2-inch-diameter crop tree at a 5-percent discount rate.

In the next section we outline the logic behind the development of the B/C factors.

Table 2--*Benefit/cost factors for combinations of site quality and vigor and diameters of crop trees at 5-, 7-, and 10-percent discount rates (use with figure 1)*

Site	Vigor	Diameter at breast height (inches)			
		2	4	6	8
		5 Percent			
High	High	0.67	0.80	0.97	1.00
High	Medium	.52	.63	.76	.78
Low	High	.49	.62	.78	.86
Low	Medium	.38	.48	.61	.68
		7 Percent			
High	High	.32	.43	.59	.67
High	Medium	.23	.31	.42	.48
Low	High	.22	.32	.45	.56
Low	Medium	.16	.23	.32	.40
		10 Percent			
High	High	.13	.20	.31	.39
High	Medium	.08	.12	.19	.25
Low	High	.08	.14	.22	.31
Low	Medium	.05	.09	.14	.19

1	2	3	4	5	6	7	8	9
Area	Site (high or low)	Average d.b.h. of leave trees (2, 4, 6, 8 inches)	Crop tree vigor (high or medium)	Precommercial thinning cost (includes slash treatment in dollars per acre	Stumpage value (current price for final harvests, in dollars per thousand board feet)	B/C factor (from table 2)	Benefit/cost ratio at user selected discount rate of __percent 1/	Financial priority
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

1/ Column 7 times column 6 divided by column 5.

Figure 1.--Worksheet for establishing financial precommercial thinning priorities.

METHOD FOR DERIVING B/C FACTORS[2/]

We have stated that in a B/C analysis of precommercial thinning alternatives the financial benefits of the thinnings relate to the additional volume of timber that will be available for harvest in commercial thinnings and the final harvest. We have assumed that the stumpage price for commercial thinnings will equal 75 percent of the stumpage price for final harvests. Present values of benefits are obtained by discounting expected benefits to year zero at a stated discount rate. Precommercial thinning costs are initial costs. As such, they occur in year zero and need not be discounted because they are already expressed in present value.

We developed the B/C factor concept to simplify the B/C calculation and the procedure of using the large B/C tables as the precommercial thinning guides. The B/C factors are derived in the following manner:

$$B/C = \sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/C.$$

ΔVi = change in volume harvest in year i (commercial thinning or final harvest).
Pi = stumpage price for harvest in year i (price for thinnings is 0.75 of price for final harvest).
df_i = discount factor in year i.

If all prices are changed by a factor R, then

$$(B/C)_R = \sum_{i=1}^{t} \left(\frac{\Delta ViPiR}{df_i}\right)/C = R \sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/C = R(B/C).$$

Likewise, if all costs are changed by a factor R',

$$(B/C)_{R'} = \sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/CR' = \frac{1}{R'} \sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/C = \frac{1}{R'}(B/C).$$

Therefore,

$$(B/C)' = \frac{R}{R'} \sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/C = \frac{R}{R'}\ (B/C).$$

Recognizing this relationship, we developed B/C factors (F) which are equal to

$$\sum_{i=1}^{t} \left(\frac{\Delta ViPi}{df_i}\right)/C;$$

when: $Pi = 1$ for final harvests,
$Pi = 0.75$ for commercial thinnings, and
$C = 1$.

Therefore, $B/C = F \times P/C$ when P is any final harvest price and C is any cost that the users of these thinning guides may suggest for the stumpage price and precommercial thinning cost associated with their thinning alternatives.

[2/] Those not interested in the derivation of B/C factors may wish to turn to the section "Use of the Guides."

USE OF THE GUIDES

The financial thinning guides are expressed as B/C's, one for each thinning alternative. The guides are in the form of a worksheet (fig. 1). The user calculates the B/C's from these data:

1. Site quality.[3/]
2. Average d.b.h. of crop trees.
3. Average crop tree vigor (as defined by one or more of the tree characteristics listed in table 3).
4. Costs:[4/] *Precommercial thinning*--Direct costs that include layout, contracts, and contract administration. *Slash treatment*--costs for meeting fire management standards.
5. Present stumpage price for final harvests exclusive of road development costs.
6. Discount rate (5, 7, or 10 percent).

A five-step procedure for using the guides is outlined here. Table 4 is a worksheet with sample data. Figure 1 is a blank worksheet which may be photocopied for use.

1. *Define precommercial thinning alternatives*. Assemble data required for each thinning alternative. Sources of this information include stand exam printouts, forest inventory, presale surveys, 5-year action plans, and onsite observations. Use current treatment costs and current stumpage prices for final harvests to define the costs and revenue associated with each precommercial thinning activity. This will insure a consistent approach to the evaluation of thinning alternatives. Future stumpage prices may change, however, and that may affect the apparent financial attractiveness but will not change the financial rankings.

Table 3--*Indicators of crop tree vigor in unthinned natural stands of ponderosa pine*

Tree characteristics	Vigor	
	Medium	High
Crown ratio	40 to 60 percent	Greater than 60 percent
Most recent decade's growth in diameter	1/2 to 1 inch	Greater than 1 inch

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[3/] A high site is a site on which dominant and codominant trees have attained an average height of 78 feet at a total age of 100 years; a low site, 70 feet at 100 years (Meyer 1961).

[4/] Costs for thinning and protection usually increase significantly as stand diameter and density increase. Use of a constant cost per acre across a range of average stand diameters is usually inappropriate.

Table 4--*Worksheet (with sample data) for establishing financial precommercial thinning priorities*

1	2	3	4	5	6	7	8	9
Area	Site (high or low)	Average d.b.h. of leave trees (2, 4, 6, or 8 inches)	Crop tree vigor (high or medium)	Precommercial thinning cost (includes slash treatment, in dollars per acre)	Stumpage value (current price for final harvests, in dollars per thousand board feet)	B/C factor (from table 2)	Benefit/cost ratio at selected discount rate of 5 percent1/	Financial priority2/
1	H	4	H	25	80	0.80	2.56	3
2	L	8	M	75	120	.68	1.09	9
3	L	2	M	25	120	.38	1.82	6
4	H	2	H	25	120	.67	3.22	1
5	H	4	H	50	120	.80	1.92	5
6	H	2	H	37.50	120	.67	2.14	4
7	L	6	H	75	120	.78	1.25	8
8	H	2	H	25	120	.67	3.22	1
9	L	4	M	25	80	.48	1.54	7
10	L	8	H	75	80	.86	.92	10

1/ Column 7 times column 6 divided by column 5.

2/ Priority number 2 is omitted because two areas have the same B/C ratio and are ranked number 1.

2. *List data for thinning alternatives in columns 1 through 6.*
3. *Locate the appropriate B/C factor* for each thinning alternative in table 2 and record them in column 7.
4. *Calculate the B/C* by multiplying the stumpage price (column 6) by the B/C factor (column 7) and dividing by the precommercial thinning cost (column 5). Record the result (B/C) in column 8.
5. *Rank alternatives to establish financial priorities.* Record priority rank in column 9. The most financially attractive thinning alternative, the one with the greatest B/C, should receive the highest ranking (priority). The alternative with the second highest B/C should receive the second highest priority, etc.

Although the above example concerns only stands with no overstory, this procedure may also be useful in stands with a mature overstory and a thinnable understory. For example, a high benefit cost ratio for thinning an understory would indicate the need for an assessment of the thrift and growth of the overstory. Thus, the financial benefits of thinning the understory could influence the timing of converting old growth to second growth. Conceivably, the combination of overstory thrift and understory thinning B/C could be used for ranking stands for overstory removal--a concept that deserves further study. The source of funding for thinning may determine whether it is appropriate to rank stands both with and without overstory, but separately. On National Forests, stands with overstory will often qualify for collection of KV5/ funds, whereas those without overstory will need to be assigned separate priorities for the use of P&M6/ funds.

APPLICATION OF THE GUIDES

Generally, a precommercial thinning opportunity exists in healthy overstocked ponderosa pine stands composed of unmerchantable size trees whenever thinning will not conflict with some higher priority use. Stands considered unmerchantable now but that will contain a salable quantity of merchantable excess trees in 10 years are not considered precommercial thinning opportunities. We are concerned with thinning stands between 1 and 8 inches in d.b.h. Even within these narrow diameter limits the forest manager is confronted with a myriad of stand conditions where thinning opportunities exist. Some of these overstocked stands have an overstory of mature trees displaying varying degrees of thrift. NFS policy is to remove overwood before the understory is thinned. Priorities for overwood removal are shown in appendix B. Stands recognized as high priority candidates for removal of their overstories should be considered for understory treatment. As soon as the overstory is removed, stands with a favorable B/C will become available for thinning.

5/ Knutson-Vandenberg Act funds set aside from harvest receipts.

6/ Appropriated funds for protection and management.

Great diversity in tree size and density can be found in young ponderosa pine reproduction in the Pacific Northwest. Much of this variation is attributed to past seed production, weather, fire, insects, disease, and logging practices. Sapling stands range from less than 1,000 trees per acre to extremes of 20,000 (fig. 2). Small pole stands can be understocked (less than 60 trees per acre) on the desert fringe or overstocked with several thousand trees per acre on higher sites. It is not unusual for adjacent sapling and pole stands to be the same age. Fire or some other agents often reduce density in a portion of a "dog hair" stand, causing faster growth and resulting in pole-size trees. Therefore, size is not a good indicator of age in overstocked stands.

Ponderosa pine responds to thinning at almost any age (Curtis 1952, Dunning 1922). Response in height and diameter growth of old merchantable ponderosa pine trees is obviously different from that of young trees. We are concerned with stands of crop trees that are 1 to 8 inches in d.b.h. and approximately 10 to 80 years old. Although all 10- to 80-year-old trees of the same size and crown dimension may not respond the same, Barrett (1973) reported that 80-year-old suppressed trees have responded at wide spacings to grow 6 inches per decade or three rings per inch. Many forest managers now recognize that these older suppressed trees have the capacity to respond and grow at acceptable rates. Age is of little concern within the precommercial thinning size classes. The real concern is the influence of crown size on growth.

Figure 2.--Unthinned ponderosa pine stand about 70 years old.

Crowns of crop trees left after precommercial thinning vary in size and in their response to release. Therefore, the average vigor of crop tree stands differs between thinning alternatives. To illustrate, consider the typical crop tree sapling growing in a stand of 2,000 trees per acre having 65 percent of its height in crown. Compare this with a crop tree in a stand of 15,000 stems with an overstory where only 40 percent of the trees' height is in the crown. The tree with the smaller crown will require more time to respond to release than the tree with the larger crown. Also, crowns often differ in density, width, and color of needles. These combined characteristics influence the vigor of the tree and consequently the speed and quantity of response of thinning (Dunning 1922).

BASIS FOR THE GUIDES

Key elements in the basis for the financial precommercial thinning guides are the stocking guides, managed yield estimates and related assumptions for thinned stands, and the investment analysis, including its assumptions and their method of application.

STOCKING GUIDES

The physical stocking guides used in the estimation of managed yields are commonly called stocking level curves. Basic features of stocking level curves are outlined in the Forest Service Silvicultural Examination and Prescription Handbook (Region 6) and figure 3. By definition in the Handbook, "a stocking level curve is a management tool used to compare the stocking of a given timber stand in relationship to a desired (biologic) stocking level under managed conditions. Generally, the curves express a desired number of trees per acre for a given diameter breast height and/or at a given age by site classes." The curves for ponderosa pine (fig. 3) are based on the growth and yield tables obtained from USDA Bulletin 630 (Meyer 1961), research data from the Pacific Northwest Experiment Station, and observations of growth of stands of various densities throughout Region 6.

The current stocking level curves show three levels of stocking: the maximum, the minimum, and the recommended levels. The upper level (fig. 3) shows the maximum number of trees desired per acre for a range of average tree sizes. It represents the upper limit of stand density beyond which vigor and growth rates deteriorate below those specified by management. The middle curve or recommended level is the density that will occupy the site producing a desirable combination of usable wood and forage for domestic and wildlife needs. The lower curve is the level of stocking that will produce the minimum acceptable yield per acre at the time of regeneration cutting.

Stocking level curves reflect full stocking level control. The recommended stocking level curve shows the number of trees of a certain diameter to be left after the silvicultural treatment is finished. The timing of the precommercial thinning is denoted by the first sharp break in the recommended level curve (point A, fig. 3). The second sharp break in the curve indicates the diameter at which the first commercial thinning will be made, in this instance 10-inch d.b.h. Periodic commercial entry occurs during the curved portion; between 50 and 70 trees are reserved for final harvest.

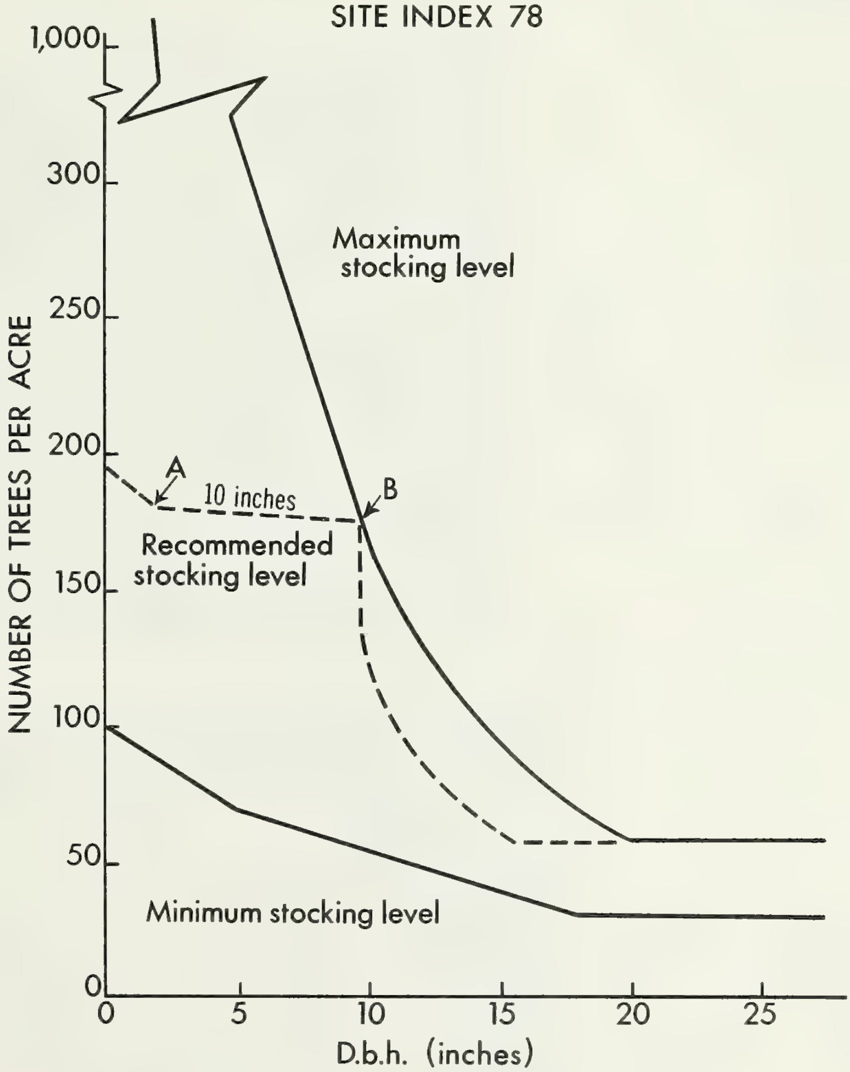

Figure 3.--Stocking level curves for Pacific Northwest ponderosa pine.

Current NFS stocking guides suggest that stand density in overstocked sapling stands be reduced to create open stands (fig. 4) with eventual benefits to other resources such as wildlife, watershed, and domestic meat production. The basic wood growth rationale for these stocking levels is that the stands of released trees remain open and growing at an acceptable rate, without incurring the expense of a second precommercial thinning, until the stand averages 10 inches in d.b.h. and a commercial thinning is possible (fig. 5). Fewer, but larger, trees are produced since all growth following the precommercial thinning accrues on stems that will be commercially harvested, except for a small amount of mortality.

Figure 4.--Ponderosa pine stand 3 years after precommercial thinning.

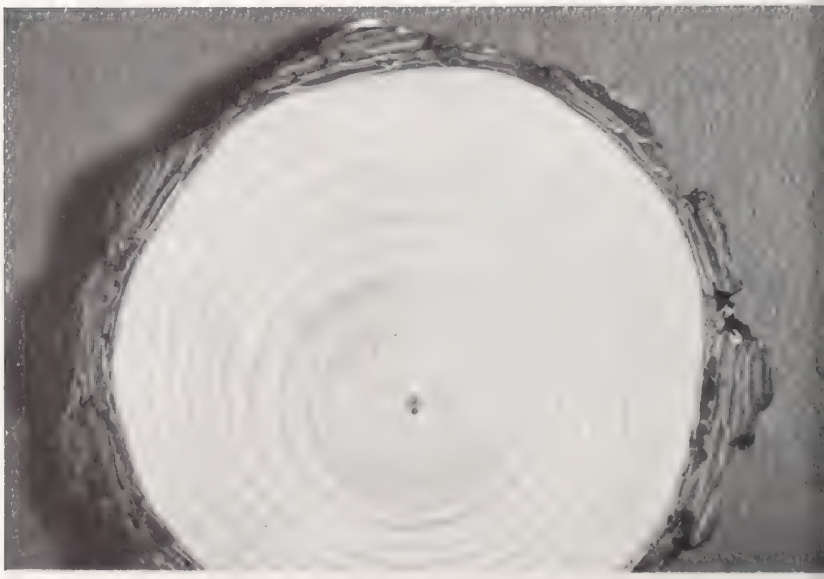

Figure 5.--Cross-section of a released ponderosa pine tree 10 years after thinning.

YIELD ESTIMATES AND ASSUMPTIONS

Growth observations of ponderosa pine stands with various densities in Region 6 and research data from the Pacific Northwest Forest and Range Experiment Station (Barrett 1973) are the basis for yield projections used in the development of the precommercial thinning guides. Pertinent yield tables are included in appendix A.

Yields were developed for a stand left unthinned and for stands thinned to NFS recommended levels with an average leave tree diameter of 2, 4, 6, and 8 inches in d.b.h. on a high site (site index 78 (Meyer 1961), 100-year basis). For example (appendix A), a sapling stand with an average diameter of 1.5 inches before thinning is thinned to 180 trees, averaging 2 inches in d.b.h. and 12 feet in height, per acre. Although the stand may actually be 50, 60, or even 80 years old, the stand is given an adjusted age of 13 years in the yield table because the tree's dimensions are similar to a natural or planted tree growing without serious competition. Similarly, the 4-inch crop trees are given an adjusted age of 22 years. Periodic existing volumes plus volumes harvested by commercial thinning are accumulated by the computer program "Managed Yield" (MGYLD).[7] The generated managed yield periodic volume increments were compared with periodic gross increments calculated from USDA Bulletin 630 to see if periodic height and diameter increments used as input for MGYLD were reasonable. The assumption here was that gross increment (net increment plus mortality) from Bulletin 630 represents a rough approximation of the potential of the site to produce wood.

Yields for a low site were estimated for the above described high site with a 2- to 4-year lag. Differences in gross yield from USDA Bulletin 630 between site indexes 70 and 78 were the basis for the lag. The effect of crop tree vigor is included in yield projections because past studies (Barrett 1969) and recent stand examinations have shown that vigor, although somewhat subjective, is a useful characteristic in judging the growth potential of ponderosa pine trees. Basic yield data assume high crop tree vigor; however, a second level, medium vigor, was recognized. Yield for medium vigor stands was assumed to be the same as for high vigor stands except for a 5-year time lag. A field guide to help distinguish the two levels of crop tree vigor is presented in table 3. Basic yield tables are presented for high site. These tables are then adjusted, as described above, to estimate yields for low site and medium vigor.

In each of the five yield projections, the first commercial harvest is made when the stand approaches

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[7] Developed by U.S. Forest Service, Division of Timber Management, Region 6, Portland, Oregon.

95 square feet of basal area and stems average 10 inches in d.b.h. Two subsequent intermediate harvests occur at 20-year intervals. Each reduces basal area to 70 to 80 square feet.

Although yield estimates extend beyond 200 years, yields for all thinning alternatives were compared when the stand attained 22 inches in d.b.h., which closely correlates with culmination of mean annual increment of merchantable cubic feet.

Yields from the unthinned stand reflect the mortality caused by the mountain pine beetle. When basal area is more than 150 square feet per acre and d.b.h. is 8 to 12 inches, conditions are right for a beetle attack that can quickly reduce basal area on average and poor sites (Sartwell and Stevens 1975). Note in this yield table that basal area is reduced substantially from age 55 to 80 years by this insect. Thus, the growing stock base in the unthinned stand is drastically reduced and yields, as a consequence, are consistently less for a given age than in the thinned stand. After a beetle attack, trees escaping the onslaught are released and they respond to the additional growing space. The stand eventually produces notable periodic increments. Total harvested volumes are not substantially different between stands that were and were not precommercially thinned (table 5); however, the timing of the commercial thinnings and the final harvest (at the target diameter of 22 inches) is delayed as shown in table 6. Without precommercial thinning, it takes more than three and one half times as long (87 versus 24 years) to reach the first commercial thinning as it does for a precommercially thinned stand with 2-inch (d.b.h.) crop trees.

In the development of the thinning guides, all yields were reduced by 10 percent to allow for naturally occurring nonstocked holes in the stand. Yields listed in appendix A reflect 100-percent stocking.

Table 5--*Volume harvested in commercial thinnings and final harvest in an overstocked stand and in precommercially thinned stands, with an assumed 90-percent stocking*

Precommercial thinning	Diameter at breast height of crop trees after precommercial thinning	Volume harvested				
		Commercial thinning			Final harvest[1/]	Total
		1	2	3		
	Inches	Board feet per acre				
No	--	2,210	2,688	2,792	21,383	29,073
Yes	2	1,324	2,891	3,440	21,980	29,635
Yes	4	1,427	2,254	2,859	22,131	28,671
Yes	6	1,863	2,595	3,038	22,978	30,474
Yes	8	1,815	2,533	2,955	23,816	31,119

[1/] Final harvest target diameter is 22 inches for all stands.

Table 6--*Timing of commercial thinnings and final harvests in an overstocked stand and a precommercially thinned stand with 2-inch crop trees*

Precommercial thinning	Years elapsed since precommercial thinning			
	Commercial thinning			Final harvest[1]
	1	2	3	
Yes	24	47	67	114
No	87	107	127	201

[1] Final harvest target diameter is 22 inches for both stands.

Investment Analysis

The financial thinning guides are based on an application of marginal investment analysis to the precommercial thinning decision involving ponderosa pine stands. The decision to thin an overstocked stand hinges on the net financial returns expected from the thinning operation. Only the measurable benefits and costs associated with investments in precommercial thinning are considered. The cost of thinning, including slash treatment for fire protection, esthetics, movement of wildlife and domestic animals, etc., and the value of the additional timber yields expected from the thinned stand are relevant to our analysis. Costs incurred prior to the precommercial thinning are, however, fixed costs that have no bearing on the thinning alternative selection process.

Unmarketed nontimber benefits and opportunity costs of precommercial thinning were not considered in the development of the thinning guides even though such costs are often associated with precommercial thinning.[8] Esthetics (and its enhancement) is an example. Daniel and Boster (1976) reported that managed, relatively open forests are preferred by the public to ponderosa pine thickets--a common natural phenomenon in ponderosa pine reproduction. Therefore, unmarketed benefits and opportunity costs that are apparent, but presently unmeasurable in financial terms, should be recognized in the decisionmaking process. Consequently, the thinning priority of a low ranking (financial) alternative may be elevated because of unusual unmarketed benefits, or vice versa.

[8] Unmarketed benefits and opportunity costs, such as adverse impacts on wildlife habitat, have an implied economic value which is often evident by the expense many people will incur to view forest scenery and the diminishing wildlife populations. How to estimate their economic value, express it in financial terms, and incorporate it into the analysis is a problem that has not been resolved.

DISCUSSION

In the introduction we outlined two reasons why the financial thinning guides are valuable to forest managers. One reason concerned the allocation of funds among precommercial thinning opportunities. The other dealt with the consistency of the approach (within the Northwest region) to the selection of overstocked ponderosa pine stands for precommercial thinning. In this section we discuss some financial implications of investing funds in precommercial thinning operations. This will help potential users to more fully understand the guides and the rationale behind their use as a tool for ranking investment opportunities among precommercial thinning alternatives.

Tables 5 and 6 show the impact that precommercial thinning of overstocked ponderosa pine sapling stands has on the volume and the timing of commercial thinnings, the final harvest, and the total volume harvested. The most meaningful financial impact on the management of these stands results from the timing of the commercial thinnings. Table 6 indicates that in a stand of ponderosa pine with 2-inch crop trees, the first commercial thinning occurs 24 years after the precommercial thinning. If the stand is not precommercially thinned, 87 years elapse from the time the stand was considered for precommercial thinning until the stand is ready to be commercially thinned. Even though the first commercial thinning is smaller in the precommercially thinned stand (1,324 vs. 2,210 board feet), it has a much larger present value ($12.32 vs. $0.95, shown in table 1) because it occurs much sooner. The economic principle of discounting accounts for the importance of the time element. For example, if the stumpage price for commercial thinnings is $30 per thousand board feet, the revenue expected from the first commercial thinning in the above described 2-inch stand, 24 years from now, is $39.72, and its present value is $12.32. Whereas, the first commercial thinning 87 years from now in the unthinned stand will generate revenues of $66.30, but its present value is only $0.95. A 5-percent discount rate is assumed here.

Care must be exercised in the assignment of the combined precommercial thinning costs and slash treatment costs to each potential thinning opportunity. It is likely that the combined precommercial thinning and slash treatment costs will be greater for the larger d.b.h. classes because of greater slash treatment expenses. It is inappropriate, however, to generalize about the thinning guides. One must consider each thinning alternative as a separate event and rank the alternative only after calculating their B/C's and recording them as illustrated in table 4.

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APPENDIX A

Yield Per Acre of Ponderosa Pine without Precommercial Thinning, Site Index 78

	Stand characteristics								Intermediate harvests				
Stand age	Number of trees	Average diameter at breast height[1/]	Average height	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top	Total volume[2/]	Mean annual increment[3/]	Number of trees	Average diameter at breast height[1/]	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top
Years		Inches	Feet	Square feet	Cubic feet	Board feet	Board feet	Cubic feet		Inches	Square feet	Cubic feet	Board feet
13	900+	1.5	12	12	--	--	--	--	--	--	--	--	--
22	900+	2.9	23	44	--	--	--	--	--	--	--	--	--
32	900+	4.2	31	92	--	--	--	--	--	--	--	--	--
45	900+	5.3	40	145	1,833	--	--	43	--	--	--	--	--
55	900+	6.1	46	192	2,841	--	--	52	--	--	--	--	--
80	304	8.3	57	114	941	--	--	12	--	--	--	--	--
100	184	10.0	62	100	1,756	6,515	6,515	18	50	11.0	33	626	2,455
120	120	12.0	71	94	2,097	8,959	11,414	23	40	12.0	31	699	2,986
140	76	14.8	79	91	2,356	11,314	16,756	26	22	14.5	25	652	3,102
160	52	17.4	84	86	2,409	12,292	20,835	27	--	--	--	--	--
180	52	19.4	90	107	3,185	17,156	25,700	29	--	--	--	--	--
200	52	21.1	94	126	3,917	21,774	30,317	29	--	--	--	--	--
220	52	22.4	98	140	4,382	24,610	33,153	29	--	--	--	--	--
240	52	23.3	100	148	4,730	26,892	35,436	28	--	--	--	--	--

1/ Average diameter of all trees.

2/ Scribner volume to a 6-inch top.

3/ Merchantable volume to a 6-inch top.

Yield Per Acre of Ponderosa Pine with Precommercial Thinning, 2-Inch Leave Tree Diameter, Site Index 78

Stand characteristics									Intermediate harvests				
Stand age	Number of trees	Average diameter at breast height 1/	Average height	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top	Total volume 2/	Mean annual increment 3/	Number of trees	Average diameter at breast height 1/	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top
Years		Inches	Feet	Square feet	Cubic feet	Board feet	Board feet	Cubic feet		Inches	Square feet	Cubic feet	Board feet
13	900+	1.5	12	12	--	--	--	--	--	--	--	--	--
37	175	10.0	38	95	1,130	3,913	3,913	31	48	11.0	32	402	1,471
60	124	13.0	56	114	2,253	9,715	11,185	44	41	13.0	38	745	3,212
80	81	16.1	68	114	2,735	13,112	17,794	48	24	16.0	34	800	3,822
100	56	18.8	78	108	2,888	15,031	23,536	48	--	--	--	--	--
120	56	21.3	86	139	4,019	22,046	30,551	50	--	--	--	--	--
140	56	23.4	94	167	5,095	28,837	37,342	50	--	--	--	--	--
160	54	24.9	100	183	5,850	33,870	42,375	49	--	--	--	--	--
180	53	25.9	106	194	6,511	38,555	47,060	47	--	--	--	--	--
200	52	26.7	110	202	6,999	41,918	50,423	45	--	--	--	--	--
220	51	27.4	113	209	7,390	44,586	53,092	42	--	--	--	--	--

1/ Average diameter of all trees.

2/ Scribner volume to a 6-inch top.

3/ Merchantable volume to a 6-inch top.

Yield Per Acre of Ponderosa Pine with Precommercial Thinning, 4-Inch Leave Tree Diameter, Site Index 78

Stand characteristics									Intermediate harvests				
Stand age	Number of trees	Average diameter at breast height1/	Average height	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top	Total volume2/	Mean annual increment3/	Number of trees	Average diameter at breast height1/	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top
Years		Inches	Feet	Square feet	Cubic feet	Board feet	Board feet	Cubic feet		Inches	Square feet	Cubic feet	Board feet
22	900+	2.9	23	44	--	--	--	--	--	--	--	--	--
43	175	10.0	42	95	1,202	4,247	4,247	28	48	11.0	32	430	1,586
60	124	12.2	55	101	1,924	7,963	9,549	39	41	12.0	32	612	2,504
80	81	15.3	67	103	2,427	11,275	15,365	43	24	15.0	30	689	3,177
100	56	18.1	77	100	2,644	13,604	20,870	44	--	--	--	--	--
120	56	20.4	85	127	3,645	19,666	26,933	45	--	--	--	--	--
140	56	22.5	93	155	4,664	26,129	33,396	46	--	--	--	--	--
160	54	24.0	99	170	5,385	30,780	38,046	44	--	--	--	--	--
180	53	25.0	105	181	6,014	35,258	42,525	43	--	--	--	--	--
200	52	25.8	109	189	6,480	38,495	45,762	41	--	--	--	--	--
220	51	26.5	112	195	6,857	41,077	48,344	39	--	--	--	--	--

1/ Average diameter of all trees.

2/ Scribner merchantable volume to a 6-inch top.

3/ Merchantable volume to a 6-inch top.

Yield Per Acre of Ponderosa Pine with Precommercial Thinning, 6-Inch Leave Tree Diameter, Site Index 78

Stand characteristics									Intermediate harvests				
Stand age	Number of trees	Average diameter at breast height 1/	Average height	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top	Total volume 2/	Mean annual increment 3/	Number of trees	Average diameter at breast height 1/	Basal area	Merchantable volume to a 6-inch top	Scribner volume to a 6-inch top
Years		Inches	Feet	Square feet	Cubic feet	Board feet	Board feet	Cubic feet		Inches	Square feet	Cubic feet	Board feet
32	900+	4.2	31	93	--	--	--	--	--	--	--	--	--
50	175	10.0	46	95	1,452	5,526	5,526	29	50	11.0	33.0	533	2,070
70	122	12.2	64	99	2,131	9,215	11,286	38	40	12.0	31.4	671	2,883
90	80	15.1	74	100	2,496	11,947	16,900	41	23	15.0	23.2	707	3,375
120	56	18.6	82	106	2,930	15,217	23,545	40	--	--	--	--	--
140	56	19.9	90	121	3,616	19,634	27,962	40	--	--	--	--	--
160	56	22.4	96	153	4,736	26,572	34,899	40	--	--	--	--	--
180	54	23.4	102	161	5,234	29,959	38,236	40	--	--	--	--	--
200	53	24.2	106	169	5,671	33,039	41,367	38	--	--	--	--	--
220	52	25.4	109	183	6,277	37,162	45,489	33	--	--	--	--	--

1/ Average diameter of all trees.

2/ Scribner merchantable volume to a 6-inch top.

3/ Merchantable volume to a 6-inch top.

Yield Per Acre of Ponderosa Pine with Precommercial Thinning, 8-Inch Leave Tree Diameter, Site Index 78

Stand characteristics									Intermediate harvests				
Stand age	Number of trees	Average diameter at breast height1/	Average height	Basal area	Merchant-able volume to a 6-inch top	Scribner volume to a 6-inch top	Total volume2/	Mean annual increment3/	Number of trees	Average diameter at breast height1/	Basal area	Merchant-able volume to a 6-inch top	Scribner volume to a 6-inch top
Years		Inches	Feet	Square feet	Cubic feet	Board feet	Board feet	Cubic feet		Inches	Square feet	Cubic feet	Board feet
45	900+	5.3	40	153	1,930	--	--	43	--	--	--	--	--
60	175	10.0	48	95	1,479	5,610	5,610	25	48	11.0	32	523	2,017
80	124	12.4	62	104	2,205	9,577	11,594	34	40	12.0	31	658	2,814
100	82	15.0	72	101	2,474	11,706	16,537	37	23	15.0	28	694	3,284
120	58	17.5	80	97	2,623	13,401	21,515	37	--	--	--	--	--
140	58	19.6	88	122	3,567	19,179	27,294	39	--	--	--	--	--
160	58	21.2	94	142	4,411	24,554	32,668	39	--	--	--	--	--
180	56	22.3	100	152	4,843	27,178	35,293	37	--	--	--	--	--
200	55	23.1	106	160	5,351	30,801	38,916	36	--	--	--	--	--
220	54	23.9	110	168	5,800	33,893	42,008	35	--	--	--	--	--

1/ Average diameter of all trees.

2/ Scribner volume to a 6-inch top.

3/ Merchantable volume to a 6-inch top.

APPENDIX B[1/]

2. Overstory Removal. The need for an overstory removal occurs both from a previously executed shelterwood harvest or seed cut and also frequently results from natural causes such as insects, disease, etc. The following priorities apply without distinction as to how the stand was created:

Priorities:

a. Lightly-Stocked Damaged Overwood with Established Understory.
Live, sound crop tree stocking level is at or above the recommended level and crop trees are considered established, i.e. at least 4-1/2 feet tall, but less than pole size. The mature overstory is below minimum stocking level and trees are in poor condition, dead, dying, or diseased such as mistletoe. Dwarf mistletoe should be evaluated as indicated in FSM 5261, Dwarf Mistletoe Control.

b. Lightly-Stocked Healthy Overwood with Established Understory.
Live, sound crop tree stocking level is at or above the recommended level and crop trees are considered established, i.e. at least 4-1/2 feet tall, but less than pole size. The mature overstory is below minimum stocking level, trees are healthy, and are no longer needed for shade.

c. Lightly-Stocked Overwood with above Minimum Stocking Underwood.
Live, sound crop tree stocking level is below the recommended level but above the minimum level and crop trees are established as above. The mature overstory is below minimum stocking level and trees are not needed for shade or additional seed.-*

*-d. Lightly-Stocked Poor Vigor Overwood with Pole Understory.
Live, sound crop tree stocking level is above the minimum level and crop trees are pole size. Mature trees are below minimum stocking level, of poor thrift, and likely will die before the stand is scheduled for a regeneration cut.

e. Lightly-Stocked Poor Vigor Overwood with Commercial Thinning Size Underwood.
Live, sound crop tree stocking level is above the minimum level and crop trees are of a merchantable size. Mature trees are below minimum stocking level, of poor thrift. Evaluate whether or not mature trees will survive until a regeneration cut is scheduled for the crop trees. If mature trees will last, do not schedule overstory removal.

[1/] From "Silvicultural Examination and Prescription Handbook," Region 6, Forest Service, U.S. Department of Agriculture, Portland, Oregon, 1974.

APP[illegible]X C

ECONOMIC PRECOMMERCIAL THINNING GUIDES FOR NORTH[illegible]NDEROSA PINE STANDS EXPRESSED IN BENEFIT/COST RATIOS

(5-pe[illegible]scount rate)

FOR 2-INCH CROP TREES

Precommercial thinning cost ($/acre)	40	80	120	160	200	240
High site - high vigor						
100	0.27	0.54	0.80	1.07	1.34	1.61
75	.36	.71	1.07	1.43	1.78	2.14
50	.54	1.07	1.61	2.14	2.68	3.21
25	1.07	2.14	3.21	4.28	5.35	6.42
High site - medium vigor						
100	.21	.42	.63	.84	1.05	1.26
75	.28	.56	.84	1.12	1.40	1.68
50	.42	.84	1.26	1.68	2.10	2.52
25	.84	1.67	2.52	3.35	4.20	5.03
Low site - high vigor						
100	.19	.39	.58	.78	.97	1.17
75	.26	.52	.78	1.04	1.30	1.56
50	.39	.78	1.17	1.56	1.95	2.33
25	.78	1.56	2.33	3.11	3.89	4.67
Low site - medium vigor						
100	.15	.30	.46	.61	.76	.91
75	.20	.41	.61	.81	1.02	1.22
50	.30	.61	.91	1.22	1.52	1.83
25	.61	1.22	1.83	2.44	3.05	3.66

Stumpage (dollars per thousand board feet)

FOR 4-INCH CROP TREES

Precommercial thinning cost ($/acre)	40	80	120	160	200	[illegible]
High site - high vigor						
100	0.32	0.64	0.96	1.28	1.60	[illegible]
75	.43	.86	1.28	1.71	2.14	[illegible]
50	.64	1.28	1.93	2.57	3.21	[illegible]
25	1.28	2.57	3.85	5.14	6.42	[illegible]
High site - medium vigor						
100	.25	.50	.75	1.01	1.26	[illegible]
75	.34	.67	1.01	1.34	1.68	[illegible]
50	.50	1.01	1.51	2.01	2.52	[illegible]
25	1.01	2.01	3.02	4.02	5.03	[illegible]
Low site - high vigor						
100	.25	.49	.74	.99	1.24	[illegible]
75	.33	.66	.99	1.32	1.65	[illegible]
50	.49	.99	1.48	1.98	2.47	[illegible]
25	.99	1.98	2.97	3.96	4.95	[illegible]
Low site - medium vigor						
100	.19	.39	.58	.77	.97	[illegible]
75	.26	.52	.77	1.03	1.29	[illegible]
50	.39	.77	1.16	1.55	1.94	[illegible]
25	.77	1.55	2.32	3.10	3.87	[illegible]

Stumpage (dollars per thousand board feet)

FOR 6-INCH CROP TREES

Precommercial thinning cost ($/acre)	40	80	120	160	200	240
High site - high vigor						
[illegible]	0.19	0.39	0.58	0.78	0.97	1.16
[illegible]	.22	.44	.67	.89	1.11	1.33
[illegible]	.26	.52	.78	1.03	1.29	1.55
[illegible]	.31	.62	.93	1.24	1.55	1.86
[illegible]	.39	.78	1.16	1.55	1.94	2.33
[illegible]	.52	1.03	1.55	2.07	2.59	3.10
High site - medium vigor						
[illegible]	.15	.30	.46	.61	.76	.91
175	.17	.35	.52	.69	.87	1.04
150	.20	.41	.61	.81	1.01	1.22
125	.24	.49	.73	.97	1.22	1.46
100	.30	.61	.91	1.22	1.52	1.82
75	.41	.81	1.22	1.62	2.03	2.43
Low site - high vigor						
[illegible]	.16	.31	.47	.62	.78	.93
175	.18	.36	.53	.71	.89	1.07
150	.21	.42	.62	.83	1.04	1.25
125	.25	.50	.75	1.00	1.25	1.50
100	.31	.62	.93	1.25	1.56	1.87
75	.42	.83	1.25	1.66	2.08	2.49
Low site - medium vigor						
200	.12	.24	.37	.49	.61	.73
175	.14	.28	.42	.56	.70	.84
150	.16	.33	.49	.65	.81	.98
125	.20	.39	.59	.78	.98	1.47
100	.24	.49	.73	.98	1.22	1.46
75	.33	.65	.98	1.30	1.63	1.95

Stumpage (dollars per thousand board feet)

FOR 8-INCH CROP TREES

Precommercial thinning cost ($/acre)	40	80	120	160	200	240
High site - high vigor						
200	0.20	0.40	0.60	0.80	1.00	1.20
175	.23	.46	.69	.92	1.14	1.37
150	.27	.53	.80	1.07	1.34	1.60
125	.32	.64	.96	1.28	1.60	1.92
100	.40	.80	1.20	1.60	2.00	2.40
75	.53	1.07	1.60	2.14	2.67	3.20
High site - medium vigor						
200	.16	.31	.47	.63	.78	.94
175	.18	.36	.54	.72	.90	1.07
150	.21	.42	.63	.84	1.05	1.26
125	.25	.50	.75	1.00	1.26	1.51
100	.31	.63	.94	1.26	1.57	1.88
75	.42	.84	1.26	1.67	2.09	2.51
Low site - high vigor						
200	.17	.35	.52	.69	.86	1.04
175	.20	.39	.59	.79	.99	1.18
150	.23	.46	.69	.92	1.15	1.38
125	.28	.55	.83	1.11	1.38	1.66
100	.35	.69	1.04	1.38	1.73	2.07
75	.46	.92	1.38	1.84	2.30	2.76
Low site - medium vigor						
200	.14	.27	.41	.54	.68	[illegible]
175	.15	.31	.46	.62	.77	[illegible]
150	.18	.36	.54	.72	.90	[illegible]
125	.22	.43	.65	.87	[illegible]	[illegible]
100	.27	.54	.81	1.08	1.35	1.62
75	.36	.72	1.08	1.44	1.81	2.17

Stumpage (dollars per thousand board feet)

Sassaman, Robert W., James W. Barrett, and Asa D. Twombly. 1977. Financial precommercial thinning guides for Northwest ponderosa pine stands. USDA For. Serv. Res. Pap. PNW-226, 27 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

This paper describes a flexible management tool designed to be applicable to thinning alternatives for an infinite number of combinations of crop tree size and vigor, site quality, thinning costs, stumpage prices, and three discount rates.

KEYWORDS: Precommercial thinning, thinning (precommercial), improvement cutting, forestry business economics, economics (forestry business), site class, diameter increment, increment (diameter), stumpage prices, cost and return accounting (forestry), timber management planning, ponderosa pine, *Pinus ponderosa*, Pacific Northwest.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

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